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MONTHLY WEATHER REVIEW

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A METHOD FOR ELIMINATING DIRECTIONAL BIAS IN WIND ROSES

BENJAMIN RATNER

C. & H. S. Division, U. S. Weather Bureau, Washington, D. C.

[Manuscript received September 14, 1950]

ABSTRACT

An easily applied statistical method for adjusting wind roses that are biased toward prime (intermediate) directions is developed on the basis of several reasonable assumptions. The method gives estimates of the excess observations from each prime (intermediate) direction and the number to be restored to each intermediate (prime) direction. An example of a directionally biased wind rose and the computations for correcting it are given.

INTRODUCTION

Most wind roses prepared from existing Weather Bureau wind records show a definite bias toward prime directions, i. e., the percentage frequency of winds from prime directions (N, NE, E, SE, S, SW, W, and NW) is indicated to be greater than those from intermediate directions (NNE, ENE, ESE, SSE, SSW, WSW, WNW, and NNW). In some cases the percentage of prime directions is as much as 4 or 5 times that of the intermediate directions; and in many of these cases the true prevailing wind direction is obscured by the bias toward the prime directions on either side of the true prevailing direction. This bias and its obviously false distortion of the wind pattern have been recognized by many of the users of Weather Bureau wind data, as well as by the Weather Bureau itself.

Weather Bureau staff members, realizing the seriousness of the situation, have investigated the causes of wind direction bias, and are well on the way toward development of methods to eliminate the bias at the sources of error. The results of this latter study will be explained in detail in a later paper. The outlook is that the Weather Bureau, within the not too distant future, will be able to prepare wind roses free of the disturbing bias now present.

However, at the present time and until such time as sufficient unbiased data are accumulated for preparation of reliable wind roses, it is necessary to face the problem of using wind roses which are known to be biased. For users of such wind roses, a corrective system has been developed and is presented in this paper. It is believed that the application of this system will result in elimination of the major portion of the bias and will give a wind rose very close to the true wind pattern.

METHOD OF CORRECTION

Insofar as several assumptions are fulfilled, the method developed in the following paragraphs will correct each wind rose only for the existing amount of bias. Furthermore, if the wind rose is unbiased, the system will not change the wind frequencies.

The assumptions made in developing this method are as follows:

1. Over a period of time, the total number of wind observations from all prime directions should equal the total number from all intermediate directions. In the Weather Bureau's study of wind bias, this assumption was thoroughly tested on wind roses of varying assymetry and was found to be valid in all but the most extreme cases of wind funnelling due to topographical environment. The number of cases falling in this category will probably not comprise more than 1 percent of the total number of wind roses.
2. The excess observations for any prime direction are a result of reducing the number of observations which should have been attributed to the two adjacent intermediate directions.
3. The excess observations for any prime direction

should be restored to the two adjacent intermediate directions according to their relative frequencies.

4. For a given observation station, each prime direction has the same constant proportion, k, of excess observations.

The symbols used in developing the method are as follows:

i wind direction. (i=N, NE, E, . . . NW for prime; i=NNE, ENE, ESE, . . ., NNW for intermediate; or i=N, NNE, NE, . . . NNW for all directions, prime and intermediate.)

P prime wind directions (N, NE, E, . . . NW).

I intermediate wind directions (NNE, ENE, ESE, . . . NNW).

F_i biased frequency for a particular direction, i.

$F_P=\sum_P F_i$, biased frequency for the prime wind directions.

$F_I=\sum_I F_i$, biased frequency for the intermediate wind directions.

F'_i adjusted frequency for a particular wind direction, i.

$F'_P=\sum_P F'_i$, adjusted frequency for the prime wind directions.

$F'_I=\sum_I F'_i$, adjusted frequency for the intermediate wind directions.

$f_i=F_i-F'_i$, excess observations for a particular wind direction, i. (Occurs for prime directions only.)

$f'_i=F'_i-F_i$, observations to be restored to a particular wind direction, i. (Occurs for intermediate directions only.)

$k=f_i/F_i$, factor by which the biased frequency of each prime wind direction must be multiplied to obtain the excess observations for that direction. By assumption 4, k is constant for a given station.

The basic equation for computing the adjusted frequency F'_i, for a given prime wind direction, i, is, by definition of f_i,

$$F'_i=F_i-f_i \tag{1}$$

To obtain f_i for use in equation (1), it is noted by definition of k that

$$f_i=k\,F_i \tag{2}$$

where k may be computed from equation (4), the derivation of which follows: Summing equations (1) and (2) over all prime wind directions (taking into account assumption 4) and combining the results give

$$k=\frac{F_P-F'_P}{F_P} \tag{3}$$

Assumption 1 ($F'_P=F'_I$) and the condition that the total number of observations must be the same before and after adjustment of the frequencies ($F'_P+F'_I=F_P+F_I$) give $F'_P=\frac{1}{2}(F_P+F_I)$, which permits equation (3) to be rewritten as

$$k=\frac{F_P-F_I}{2F_P} \tag{4}$$

The factor k is thus expressed in terms of the readily computed values F_P and F_I, and the f_i and F'_i for each prime direction may now be determined from equations (2) and (1).

To determine the adjusted frequency, F'_i, for each intermediate direction the basic equation is, by definition of f'_i,

$$F'_i=F_i+f'_i \tag{5}$$

The f'_i in equation (5) may be computed directly by use of assumptions 2 and 3, which stated algebraically give

$$f'_i=\left(\frac{F_i}{F_i+F_{i+2}}\right)f_{i+1}+\left(\frac{F_i}{F_i+F_{i-2}}\right)f_{i-1} \tag{6}$$

where the f_i have already been computed in adjusting the prime direction frequencies.

On the basis of the above algebraic developments, the following is a summary of the steps to be taken in adjusting a biased wind rose at a particular station:

1. Compute F_P and F_I by summing the observations for prime and intermediate directions, respectively.
2. Compute the ratio $\frac{F_P-F_I}{F_P}$ and from equation (4) determine k.
3. From equation (2) obtain the excess observations, f_i, for each prime direction.
4. From equation (1), obtain the adjusted frequency F'_i, for each prime direction.
5. From equation (6) obtain the excess observations, f'_i, to be restored to each intermediate direction.
6. From equation (5) obtain the adjusted frequency, F'_i, for each intermediate direction.

Where wind rose data are available for different speed groups, the method should be applied separately to each group, as it has been established that bias differs with speed groups, with the greatest amount of bias in the lower speed groups.

So far, this system of adjustment has been discussed only as it applies to wind roses that are biased toward prime directions. By interchanging the roles of the prime and intermediate directions, i. e., by taking the excess from the intermediate directions and restoring it to the prime, the system applies equally well to wind roses that are biased toward the intermediate points. Weather Bureau files also contain many of these cases.

EXAMPLES

Table 1 illustrates how the system is applied in practice. Here, the actual wind rose data for Miami, Fla.,

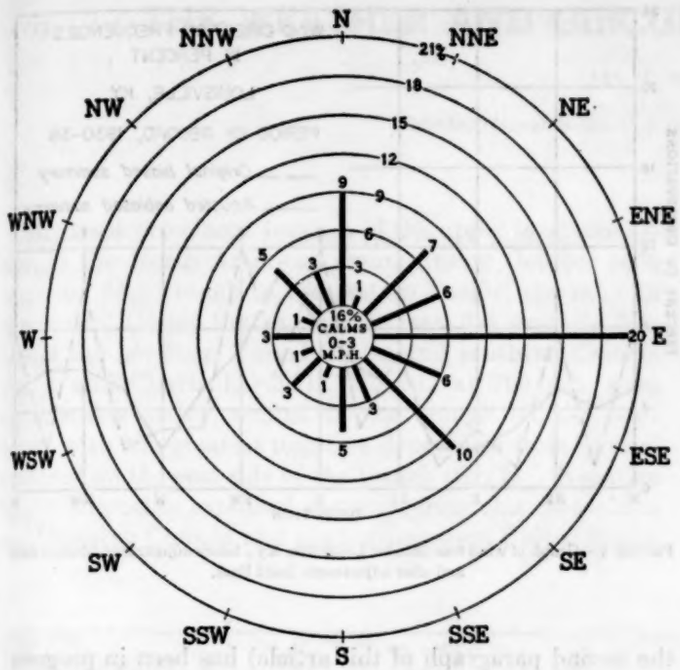

FIGURE 1.—Original biased wind rose for Miami, Fla., based on the values shown in column 1 of table 1.

TABLE 1.—*Correction method to eliminate directional bias in wind roses*

Miami, Florida (Jan. 1932 through Dec. 1938)

Direction	F_i Original number of observations	f_i Excess observations (from prime)	f'_i=(3)+(4) Restored observations (to intermediate)		F'_i Adjusted number of observations
	(1)	(2) (−)	(3) (+)	(4) (+)	(5)
N	5,042	1,556			3,486
NNE	879		554	228	1,661
NE	3,768	1,163			2,605
ENE	3,597		935	1,724	6,256
E	11,257	3,475			7,782
ESE	3,662		1,751	1,135	6,548
SE	5,538	1,710			3,828
SSE	1,855		575	691	3,121
S	2,841	877			1,964
SSW	498		186	236	920
SW	1,674	517			1,157
WSW	595		281	270	1,146
W	1,732	535			1,197
WNW	585		265	233	1,083
NW	2,807	867			1,940
NNW	1,588		634	1,002	3,224
TOTAL	47,918	10,700	10,700		47,918
CALM	9,145				
	57,063				

Computational steps:

1. From original data (column 1), determine the total number of observations for both prime and intermediate directions. Total prime, F_P=34,659. Total intermediate, F_I=13,259.

2. Determine the factor k:

$$k=\frac{F_P-F_I}{2F_P}=\frac{34,659-13,259}{2(34,659)}=0.3087$$

3. Multiply each prime direction by factor 0.3087, obtaining values in column 2, to be subtracted from each prime direction.

4. Determine the number of observations to be restored to each intermediate direction by dividing excess observations of each prime direction (column 2) between adjacent intermediate directions, in a manner proportional to their relative magnitude. Tabulate these values in columns 3 and 4.

Example: Divide 1163 at NE between NNE and ENE in a 879 to 3597 proportion, or 228 to NNE and 935 to ENE.

5. Algebraically sum each line according to the signs at the head of each column, thus obtaining the adjusted frequencies (column 5).

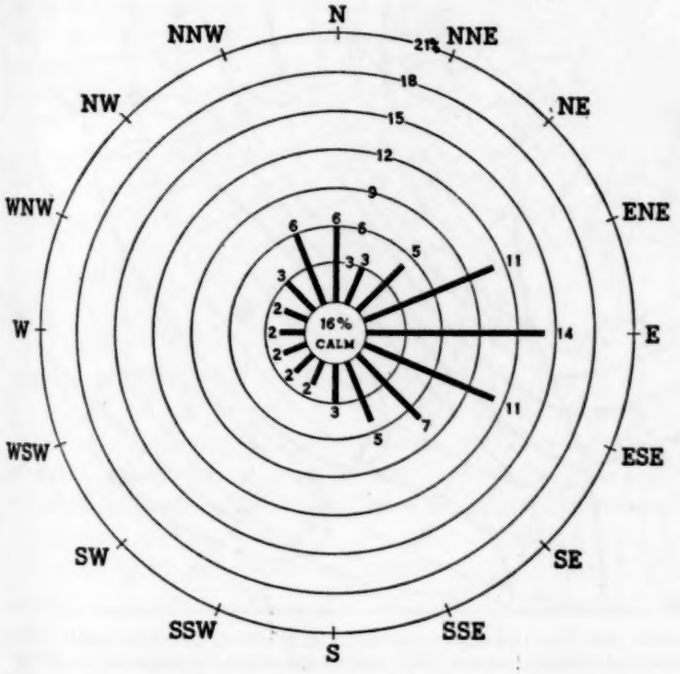

FIGURE 2.—Adjusted wind rose for Miami, Fla., based on the values shown in column 5 of table 1.

have been adjusted as indicated by the computational steps at the foot of the table. Figure 1 is the original uncorrected wind rose drawn from the values shown in column 1 of table 1. In every case the prime direction frequency line is longer than the frequency lines for the intermediate directions on each side of it. Since wind is a continuous function, it is unlikely that a wind pattern with greater frequency in all prime directions could exist over an extended period of time.

Figure 2 is the wind rose for the same station and period after adjustment by the described method. Although the prevailing direction is still E, the decrease from the peak point is gradual, i. e., 14 percent from E, 11 percent from ESE, 7 percent from SE, 5 percent from SSE, etc., rather than the "saw-tooth" effect of the corresponding 20 percent from E, 6 percent from ESE, 10 percent from SE, and 3 percent from SSE as indicated by the unadjusted wind rose (fig. 1).

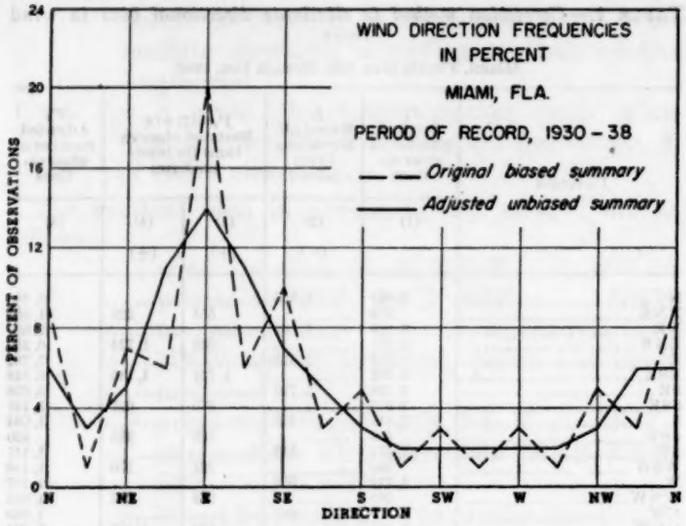

FIGURE 3.—Graph of wind rose data for Miami, Fla., before adjustment (dashed line) and after adjustment (solid line).

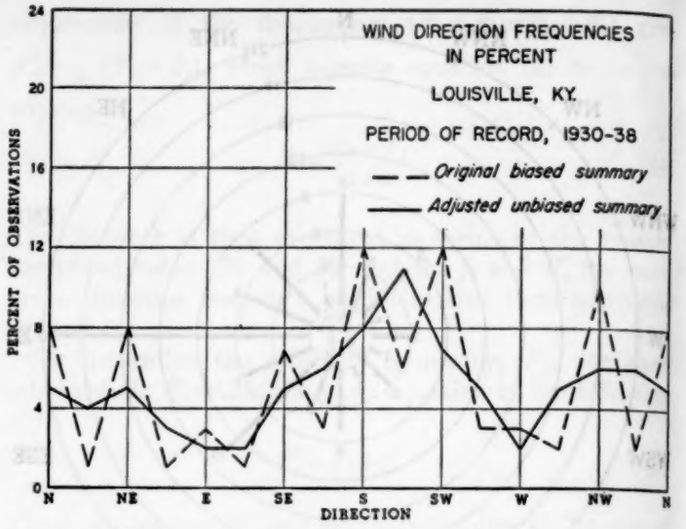

FIGURE 4.—Graph of wind rose data for Louisville, Ky., before adjustment (dashed line) and after adjustment (solid line).

The changes created by adjustment in the Miami wind rose can best be seen in figure 3, which is merely a graph of the wind rose data before and after adjustment. Figure 4 shows the same type of "before and after" wind rose data for Louisville, Ky. Here by the adjusting procedure, the prevailing directions of S and SW have given way to a prevailing wind from SSW. A similar result has been obtained in adjusting wind roses for other stations; and although the Weather Bureau's program for eliminating the bias at the original source (mentioned in the second paragraph of this article) has been in progress for a few months only, unbiased wind roses resulting from the new program indicate that for these same stations the change in prevailing direction produced by the adjustment is justified.

ACKNOWLEDGMENT

Grateful acknowledgment is given to Mr. Howard Engelbrecht for his assistance in the statistical presentation of this paper.

THE WEATHER AND CIRCULATION OF OCTOBER 1950[1]

JAY S. WINSTON

Extended Forecast Section, U. S. Weather Bureau, Washington, D. C.

The most prominent features of the upper level circulation in the North American region during October 1950 were the deep trough in the eastern Pacific, the ridge in the central United States, and the fast, flat westerly flow across the northern United States and southern Canada (fig. 1 and Charts IX–XI). Heights at 700 mb. were considerably below normal in the trough off the west coast, with the greatest negative departures from normal centered on the east side of the trough (fig. 1). Negative height anomalies extended eastward from this center into southwestern Canada and the northwestern United States so that the ridge in Saskatchewan, Alberta, and North Dakota was weaker than normal. Over most of the remainder of the United States heights were above normal with a ridge of positive height anomaly stretching east-northeastward from Arizona to New England. Other circulation features of interest were the abnormally deep trough in the Gulf of Mexico, which was mainly a wave in the easterlies, and the trough off the east coast, which was weaker-than-normal southwest of Newfoundland.

[1] See Charts I–XI, following p. 196, for analyzed climatological data for the month.

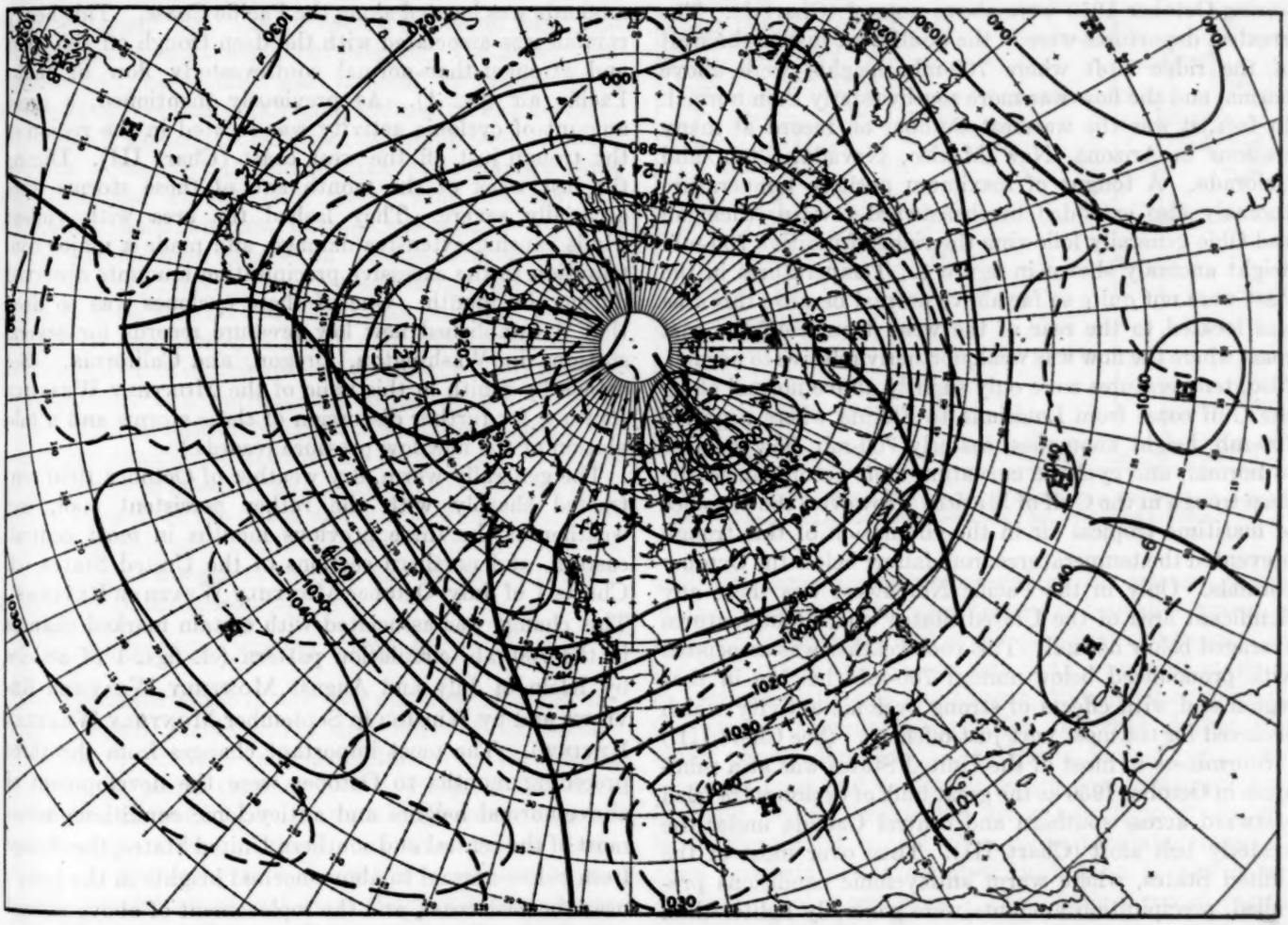

FIGURE 1.—Mean 700-mb. chart for the 30-day period September 30–October 29, 1950. Contours at 200-foot intervals are shown by solid lines, 700-mb. height departures from normal at 100-foot intervals by dashed lines with the zero isopleth heavier. Anomaly centers and contours are labeled in tens of feet. Minimum latitude trough locations are shown by heavy solid lines.

The presence of a well-defined trough off the west coast and fast westerlies across northern sections of the United States allowed most of the country to be flooded with mild Pacific air during the month. Southwesterly flow relative to normal throughout the West and along the northern border from the Pacific to the Lakes (fig. 1) also is indicative of the predominance of flow from lower and middle latitudes of the Pacific. These conditions minimized both the frequency and intensity of outbreaks of cold Canadian polar air into the United States. Chart II shows that most of the anticyclones during the month followed a nearly west to east path across the United States and Canada. Thus, most Canadian Highs never crossed into the United States and most Highs in the United States were of Pacific origin. (Most of the Highs whose tracks in Chart II appear to originate just to the east of the Continental Divide actually developed from surges of Pacific air which came across the mountains.)

With these considerations in mind, it is not surprising that surface temperatures in nearly all of the United States during October 1950 were above normal (Chart I). The greatest departures were in the Southwest just to the west of the ridge aloft where 700-mb. heights were above normal and the flow was more southwesterly than normal. In fact, it was the warmest October on record at many stations in Arizona, New Mexico, Nevada, Utah, and Colorado. A tongue of maximum positive temperature anomaly also extended northeastward toward Michigan and Ohio generally following the ridge of positive 700-mb. height anomaly shown in figure 1. Temperatures in the East were not quite so far above normal because this area was located to the rear of the weak trough off the east coast where the flow was weak northerly relative to normal. Also, temperatures were only slightly above normal along the Gulf coast from Louisiana to Florida where negative 700-mb. height anomalies, easterly 700-mb. flow relative to normal, and cyclonic curvature aloft accompanied the deep trough in the Gulf of Mexico. However, the presence of maritime tropical air in the circulation of this trough prevented the temperatures from falling below the October normals. Only in the Pacific Northwest was there any significant area of the United States where temperatures averaged below normal. This cool weather was associated with pronounced below-normal 700-mb. heights in that region and with effects of strong cyclonic activity which occurred for the most part just offshore. (See Chart III.)

Storminess in most of the United States was at a minimum in October 1950 as the great bulk of cyclones traveled eastward across southern and central Canada under the westerly belt aloft (Chart III). Thus over most of the United States, where warm anticyclonic conditions prevailed, precipitation amounts were generally lighter than normal (Chart V and inset). Driest conditions were observed in the Southwest where many stations in Arizona, New Mexico, Utah, and Texas reported the smallest amounts on record for October (0 to .01 in.). There were a few localized areas of heavier-than-normal precipitation in northern Minnesota, eastern Nebraska and Kansas, and the Lower Lakes region. This rainfall is difficult to explain from the monthly mean maps since most of it occurred as locally heavy precipitation accompanying the few cyclones that traversed the northern United States during the month (Chart III). Similarly the heavy amounts near El Paso and in southeastern New Mexico fell in thundershowers connected with a cold front early in the month.

Precipitation was also heavy in sections of the South Atlantic and Gulf States in connection with the deep easterly trough in the Gulf of Mexico (fig. 1). Two tropical storms, which entered Florida in the third week of the month (Chart III), were associated with this trough. The entire east coast of Florida bore the brunt of this tropical rainfall with amounts for the month between 10 and 15 inches.

The most widespread area of above-normal precipitation amounts was located along the Pacific Coast. This heavy rainfall was associated with the deep trough off the coast and stronger-than-normal southwesterly flow of moist Pacific air (fig. 1). As previously mentioned, a great amount of cyclonic activity was located in the region of the trough just off the west coast (Chart III). During the last week of the month two of these storms were especially severe. They lashed the area with violent winds causing extensive damage, and made a major contribution to the excessive precipitation amounts observed during the month. One of these cyclones was so deep that it established new low pressure records for several stations in Washington, Oregon, and California. (See article by Smith in this issue of the MONTHLY WEATHER REVIEW for further discussion of these storms and a tabulation of the new low pressure records.)

The generally warm, dry weather of October 1950 contrasted sharply with the rather persistent cool, wet weather of the three previous months in most central, eastern, and northern sections of the United States (cf. Charts I of July–October MONTHLY WEATHER REVIEWS). This change was associated with certain marked changes in the 700-mb. circulation pattern (cf. figs. 1 of articles by Klein in July and August MONTHLY WEATHER REVIEWS and by Winston in September MONTHLY WEATHER REVIEW). The most important changes from the three preceding months to October were the development of above-normal heights and anticyclonic conditions across most of the central and southern United States, the change from below-normal to above-normal heights in the trough near the east coast, and the replacement of above-normal heights by below-normal heights in the ridge in western Canada and the northwestern United States.

THE INTENSE PACIFIC COAST STORMS OF OCTOBER 26-28, 1950

CLARENCE D. SMITH, JR.

WBAN Analysis Center, U. S. Weather Bureau, Washington, D. C.

DAMAGE BY THE STORMS

On October 25, the cyclone that became the first of two destructive storms to affect northern California, Oregon, Washington, and Idaho began developing 850 miles west of Portland, Oreg. The strong winds and heavy rainfall that preceded and accompanied the subsequent frontal passages caused widespread damage. All sections of Washington suffered structural damage. The strong winds, with gusts as high as 75 m. p. h., took their usual toll of trees uprooted, power lines downed, and crops damaged. In the Hood River Valley (Oregon) much of the apple crop was blown from the trees. Forty to sixty percent of the seed-clover fields of eastern Oregon were destroyed [1]. Losses caused by wind and rain were estimated at $2,000,000 in Oregon. The heavy rainfall brought harvesting and farming operations to a standstill in Washington, Oregon, and central and northern California. Losses in California, excluding flood damage, exceeded $500,000. In Sacramento, wind damage alone was estimated at $250,000. Some wind damage was suffered in Idaho, but crop damage was small.

Flooding of most streams in western Oregon resulted from the heavy rains. The most serious damage occurred in the Eugene area on the Willamette River, in Douglas County on the Umpqua River and tributaries, in the Grants Pass to Medford area on the Rogue River, and at Myrtle Point and surrounding areas on the Coquille River. The American National Red Cross helped evacuate more than 2,000 families in Oregon and reported several towns isolated for days. Seven persons lost their lives as a result of the floods and strong winds. In California the Eel and Smith Rivers flooded. The Eel River flood, at a stage of 21 feet, was the first on record for so early in the season [2].

CLIMATOLOGICAL COMPARISONS

The combined effect of the two major storms and the series of small, stable waves that followed the second storm was to produce daily precipitation in the coastal region for the period October 25–30. Figure 1 illustrates the total rainfall at selected stations in the storm area for that period. (Many other stations received large amounts.) The isohyets were drawn to conform to the pattern revealed on annual average precipitation charts, which reflect the influence of topography [3]. As figure 1 shows, the rainfall of the storms fits the average pattern

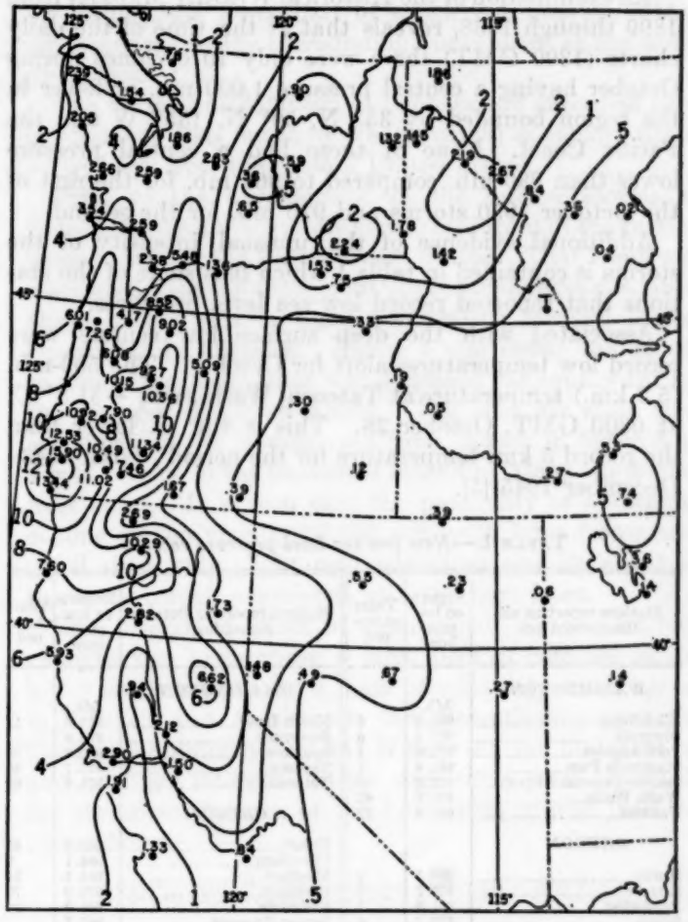

FIGURE 1.—Total precipitation from 1230 GMT, October 25 to 1230 GMT, October 30, 1950. Values plotted in inches and hundredths. Isohyets labeled in inches.

well with large amounts observed on the western slopes of the Coast and Cascade Ranges and smaller amounts on the eastern slopes and in the principal valleys such as the Willamette and Sacramento. At numerous stations in northern California and Oregon, 10 percent or more of the annual average precipitation occurred during the 5-day period illustrated. At Grants Pass, Oreg., both a new 24-hour and a 48-hour record were obtained, and at Bend, Oreg., 5.88 inches set a new October record. In California, 34 out of 37 stations tabulated received more precipitation in October 1950, than in any other previous October on record. The length of record varied from 4 to more than 60 years. However, it is significant that at Eureka, Calif., and Upper Mattole, Calif., where

the record goes back 62 years, the total exceeded the previous October record by more than 4.5 inches. Eureka reported 13.04 inches and Upper Mattole, 25.62 inches. At Gasquet Ranger Station, Calif., 26.10 inches of rain fell during the period October 25–30 and at Eureka a new 24-hour record of 5.83 inches was established [2].

An examination of the Historical Weather Maps [4] from 1899 through 1938, reveals that at the time of the daily charts (1300 GMT) there were only 10 cyclones during October having a central pressure 1,000 mb. or lower in the region bounded by 35° N, 50° N, 135° W and the Pacific Coast. None of these had a central pressure lower than 980 mb. compared to 967 mb. for the first of the October 1950 storms and 970 mb. for the second.

Additional evidence of the unusual intensity of the storms is contained in table 1 which lists some of the stations that reported record low sea level pressures.

Associated with the deep surface low centers were record low temperatures aloft for October. The 500-mb. (5.2 km.) temperature at Tatoosh, Wash., was −31.8° C. at 0300 GMT, October 28. This is 4.8° C. lower than the record 5 km. temperature for the period March 1943–December 1945 [5].

TABLE 1.—*New low sea level pressure records*

Stations reporting all-time record low	Reported low pressure	Years of record	Stations reporting October record low	Reported low pressure	Years of record
WASHINGTON			*WASHINGTON*		
	Mb.			*Mb.*	
Ellensburg	981.0	6	North Head	973.6	17
Olympia	977.3	6	Stevenson	972.9	------
Port Angeles	973.6	4	Spokane	983.4	70
Stampede Pass	981.4	7	Tacoma	977.7	48
Seattle-Tacoma Airport	977.3	6	Tatoosh	971.6	61
Walla Walla	980.7	65			
Yakima	980.4	32	*OREGON*		
OREGON			Baker	989.2	61
			Meacham	984.1	8
Burns	989.5	2	Medford	984.4	24
Eugene	979.7	6	Portland	979.0	79
Pendleton	981.0	5	Roseburg	981.0	73
Salem	979.7	6	Sexton Summit	982.7	------
CALIFORNIA			*CALIFORNIA*		
Blue Canyon	994.9	2	Eureka	986.8	51
Mount Shasta	984.5	2	Oakland	1,000.7	16
Red Bluff	991.9	63	Sacramento	997.6	74

ANTECEDENT SYNOPTIC CHANGES

In order to study the development of the storms, it is helpful to consider the upper air and surface changes that preceded the first storm. On October 17 and 18 a Low at 500 mb. with a trough trailing southwestward passed south of the weather ship at 50° N, 145° W (Station P). The Low and its accompanying trough moved into the region between 140° W and the United States coast on October 19. There the trough halted and remained until an influx of the much colder air on October 24 and 25.

Those events were naturally accompanied by a change in the direction of flow through the region between 140° W and the North American coast. Figures 2 and 3 show the weak low center that replaced the strong southwesterly

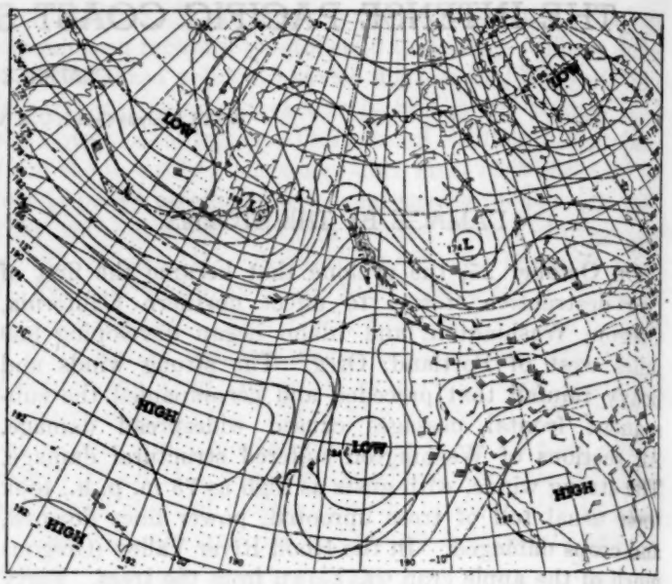

FIGURE 2.—500-mb. chart for 1300 GMT, October 23, 1950. Contours (solid lines) at 100-foot intervals are labeled in hundreds of geopotential feet. Isotherms (dashed lines) are at intervals of 5° C. Barbs on wind shafts are for speeds in knots (pennant=50 knots, full barb=10 knots, and half barb=5 knots).

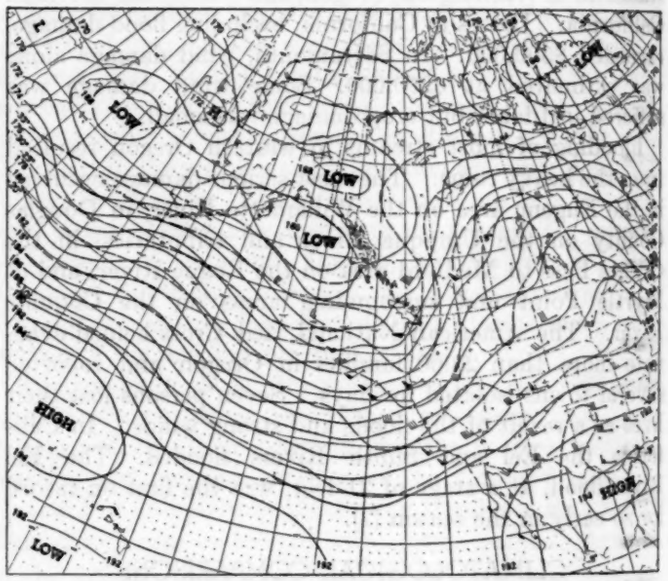

FIGURE 3.—500-mb. chart for 0300 GMT, October 26, 1950.

flow over the Gulf of Alaska and the establishment of a wide stream of westerlies in the region between 140° W and the United States coast. That change helped set up a broad, steering, current from the Aleutian Island region southeastward into the region just west of Washington and Oregon.

On October 22, a mass of very cold air represented by the −30° C. isotherm at 500 mb. moved eastward out of Siberia (fig. 2). By examining the subsequent 500 mb. charts the cold air (progress of the −30° C. isotherm) can

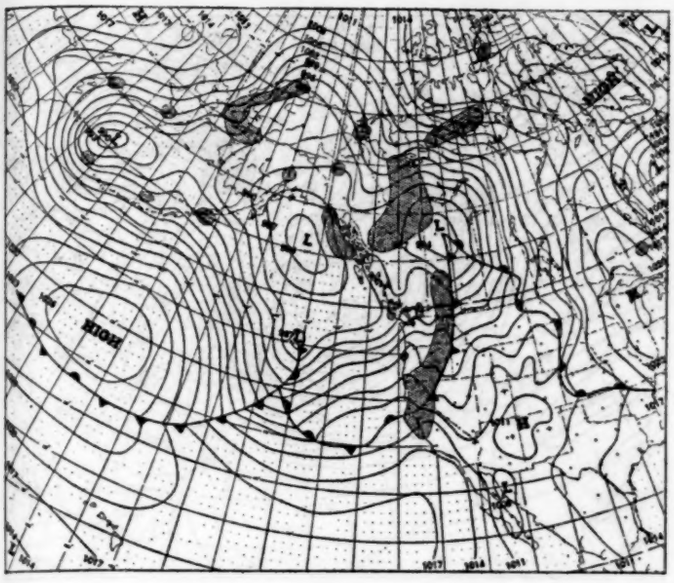

FIGURE 4.—Surface weather chart for 0030 GMT, October 26, 1950. Shading indicates areas of active precipitation.

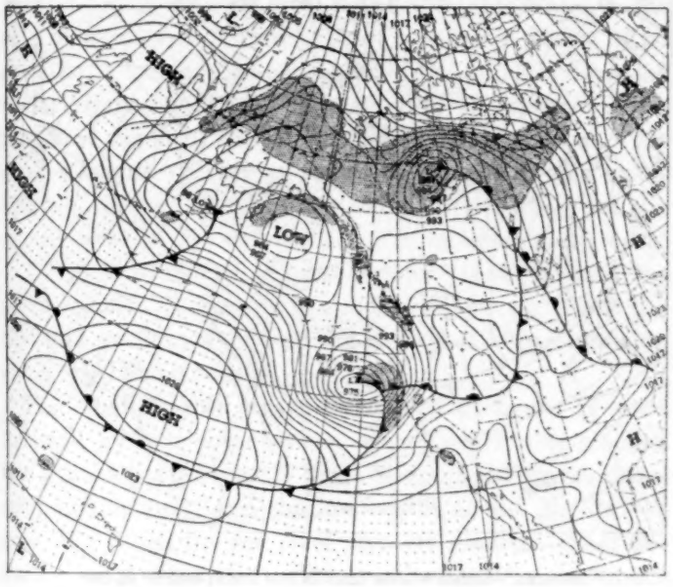

FIGURE 5.—Surface weather chart for 1830 GMT, October 26, 1950.

be followed over the Aleutian Islands, past the weather ship at Station P on October 24, over Tatoosh at 0300 GMT, October 26 (fig. 3), and to Edmonton, Alberta, by 1500 GMT October 26. A comparison of figures 2 and 3 illustrates the upper air change and shows that the temperature in the region just west of Oregon fell from about −16° C. to about −26° C.

Associated with the 500-mb. changes described were marked temperature changes at 200 mb. A large mass of relatively warm air, delineated by the −45° C. isotherm, was brought over the Gulf of Alaska region, and the main stream of the westerlies was directed into the area just west of Washington and Oregon. That situation also helped steer the low centers farther south under the warm air in the stratosphere. The record low pressures that occurred later were partly caused by the warm air above 200 mb. which contributed relatively little weight to the air column, the lower part of which was heavier, colder air compared to the surrounding atmosphere at the same elevations.

The vertical distribution of temperature described here is similar to that found by Vederman [6] in rapidly deepening Lows over the eastern United States.

Prior to the development of the intense storms of October 26–28 a moderately strong cold front at the surface passed through the Pacific Coast States. That front was associated with the antecedent upper air changes described above and is seen in figure 4 extending through Idaho, Oregon, and California. Figure 4 also shows the extent to which the polar front was displaced far southward by the changes described above. The cold air aloft that accompanied the leading cold front is seen in figure 3 as a cold tongue in the isotherms extending along the northwest coast. It is seen that the possibility of additional cooling in the vicinity of 500 mb. with later fronts was small since only slight cold advection was indicated in the weak trough associated with the next front.

The integrated effect of these upper air and surface changes was to establish a large pool of cold air in the lower levels capped by a mass of relatively warm air at high levels and to sharpen the discontinuity over the Pacific at approximately 35° N between the major warm and cold air masses. Those conditions were favorable for the intensification of the Lows that moved into the region later.

SYNOPTIC CONDITIONS DURING STORMS

The first of the intense storms is shown in figure 4 near 45° N, 140° W when it was in an early stage. The low center developed on an old occlusion the northern end of which had frontolized earlier. Eighteen hours after it was first noted, it had moved to a point 400 miles west of Medford and deepened 15 mb. (fig. 5). The speed of the low center was 35 m. p. h. or approximately 70 percent of the wind speed at 500 mb. The cold front associated with the Low reached the Oregon-Northern California coast around 2130 GMT, October 26, and swept rapidly eastward. At the same time, the low center moved northeastward and deepened another 5 mb. to a central value of 967 mb. (fig. 6). By 0300 GMT, October 27, a small closed Low had formed at 500 mb. (fig. 7), and the cold trough associated with the cold front had moved to the coast. The strongest, most damaging winds were experienced on October 26, with the passage of the cold front, and later on October 27. After the frontal passage, the

917883—51——2

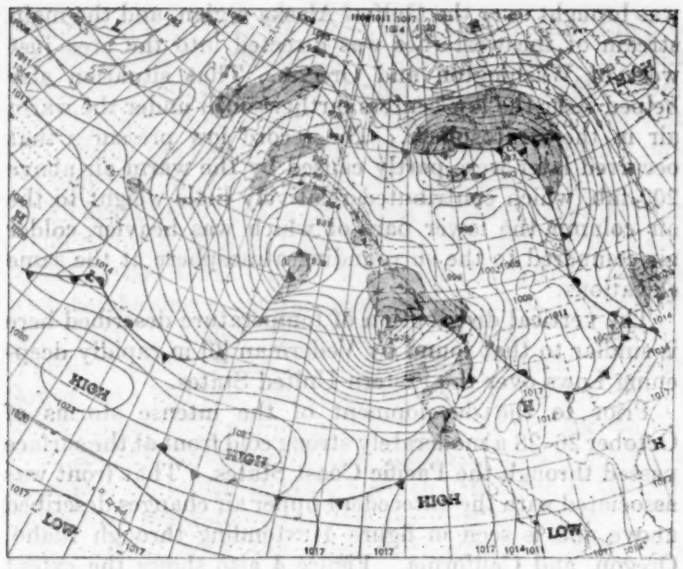

FIGURE 6.—Surface weather chart for 0630 GMT, October 27, 1950.

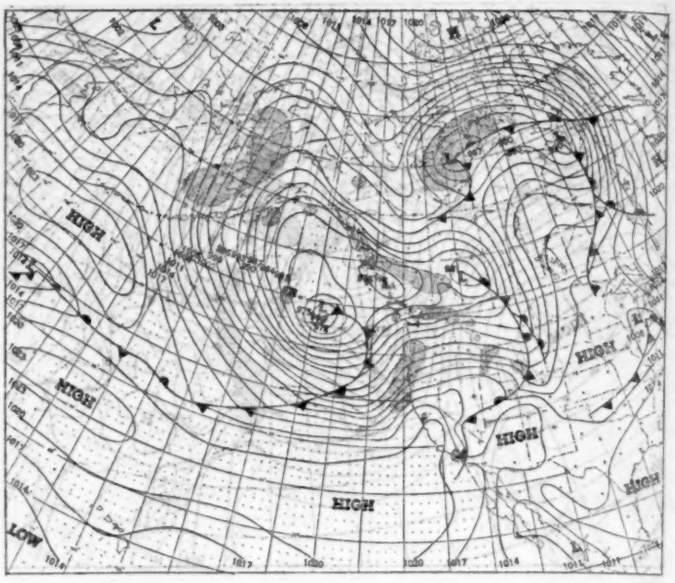

FIGURE 8.—Surface weather chart for 1830 GMT, October 27, 1950.

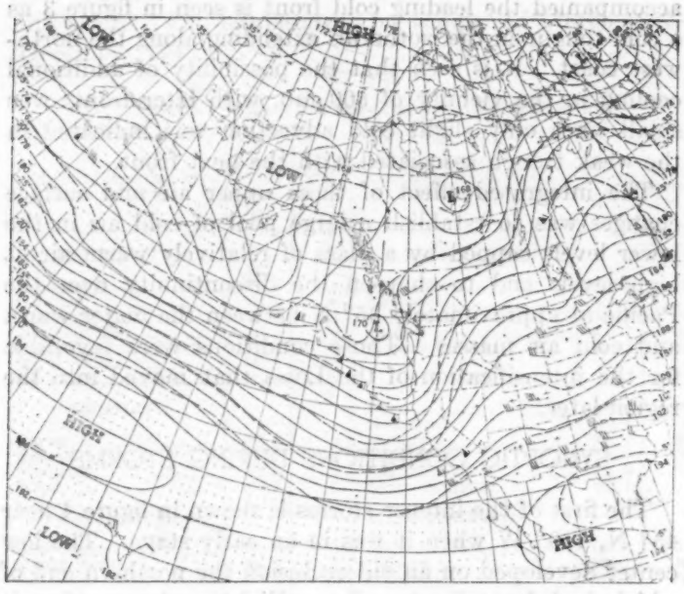

FIGURE 7.—500-mb. chart for 0300 GMT, October 27, 1950.

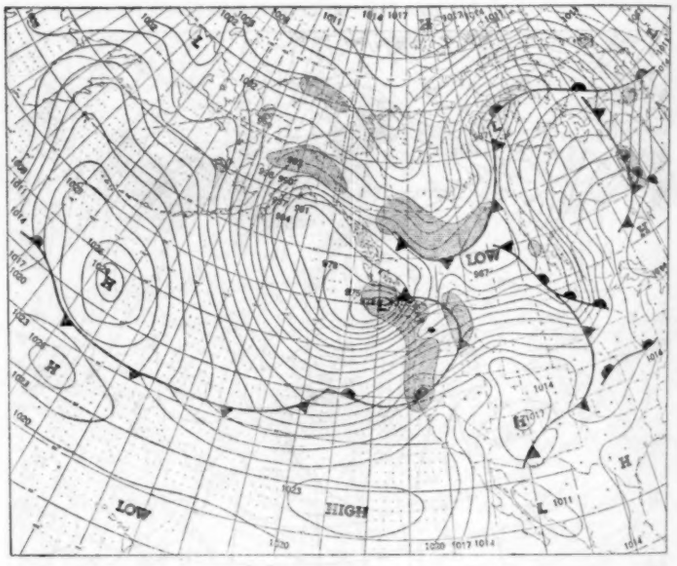

FIGURE 9.—Surface weather chart for 0330 GMT, October 28, 1950.

pressure immediately began to return toward normal. At 1230 GMT and 1530 GMT, October 27, several stations in Oregon and Washington reported 3-hourly pressure tendencies of +9.8 mb. Portland reported +10.2 mb. for the period 1230–1530 GMT, October 27.

The second storm first appeared as a small low pressure center located about 100 miles north of Cold Bay, Alaska, with a weak cold front extending southwestward (fig. 5). By 0630 GMT, October 27, the Low had moved to a point near Station P, consolidated with an old Low that had been in the Gulf of Alaska, and deepened 16 mb. (fig. 6). The small upper air trough associated with the second storm is seen in figure 7 between Station P and the Aleutian Islands. The rapid eastward progress of the cold front associated with the second Low is seen by comparing figures 6 and 8. At approximately 2330 GMT, October 27, the winds behind the cold front were reported by the Lark Dog reconnaissance flight (San Francisco to Station P) to be 47 to 63 m. p. h. at 1,500 feet. Figure 9 illustrates the continued rapid sweep eastward of the cold front.

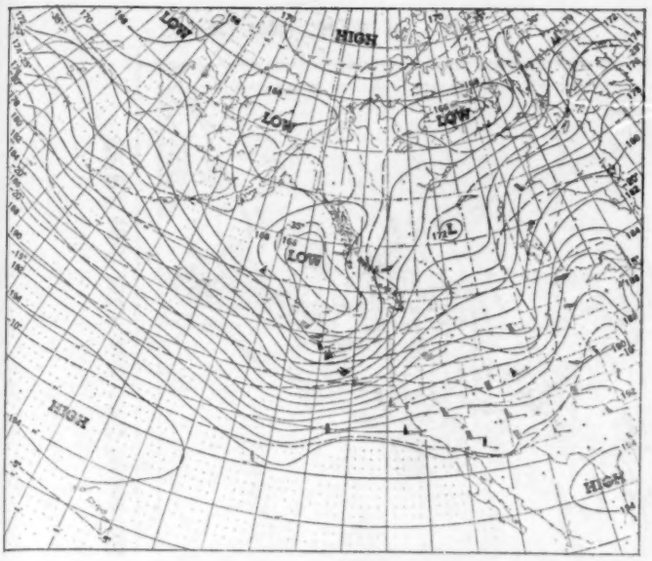

FIGURE 10.—500-mb. chart for 0300 GMT, October 28, 1950.

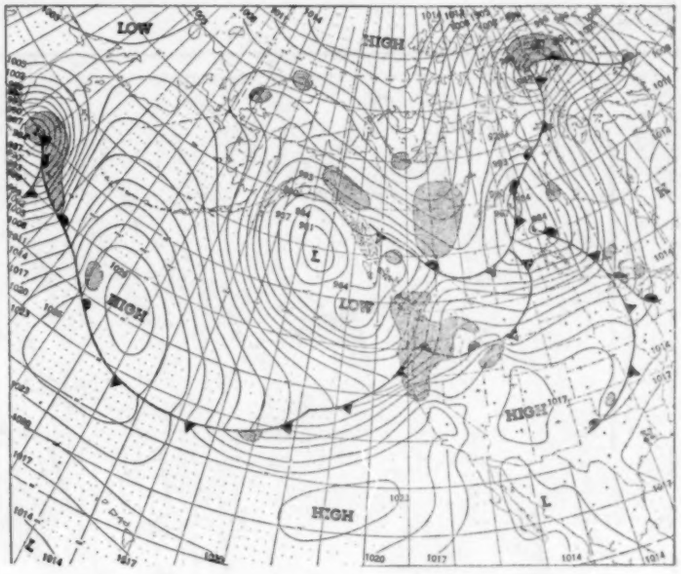

FIGURE 11.—Surface weather chart for 1830 GMT, October 28, 1950.

During the 12-hour interval between figures 8 and 9, the cold front moved 700 miles or at a speed in excess of 50 m. p. h. Whereas the low center of the first storm passed as far south as 41° N, the center of the second storm remained north of 48° N and reached the coast at Vancouver Island. Figure 10 shows the tongue of cold air at 500 mb., brought in with the second front, which set the record 500-mb. low temperature for October at Tatoosh.

The first of the small, stable waves that followed the second storm is seen in figure 9. Figure 11 shows the first and second waves, and the large area of precipitation along the Pacific coast.

The small, stable waves illustrated in figure 11 were followed by two other waves, one of which also reached the United States coast. Since none of the waves deepened significantly, and the low center at 49° N, 134° W gradually filled, the sea level pressure gradient along the Pacific coast weakened. This resulted in the abatement of strong winds and brought the regime to an end.

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2. U. S. Weather Bureau, *California Monthly Weather and Crop Bulletin*, October 1950, vol. 1, No. 32, San Francisco, Calif.
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5. U. S. Weather Bureau, "Extreme Temperatures in the Upper Air," *Technical Paper No. 3*, Washington, D. C., July 1947.
6. J. Vederman, "Changes in Vertical Mass Distribution over Rapidly Deepening Lows," *Bulletin of the American Meteorological Society*, vol. 30, No. 9, November 1949, p. 303–309.

U. S. GOVERNMENT PRINTING OFFICE: 1951

Chart I. Departure (°F.) of the Mean Temperature from the Normal, and Wind Roses for Selected Stations, October 1950

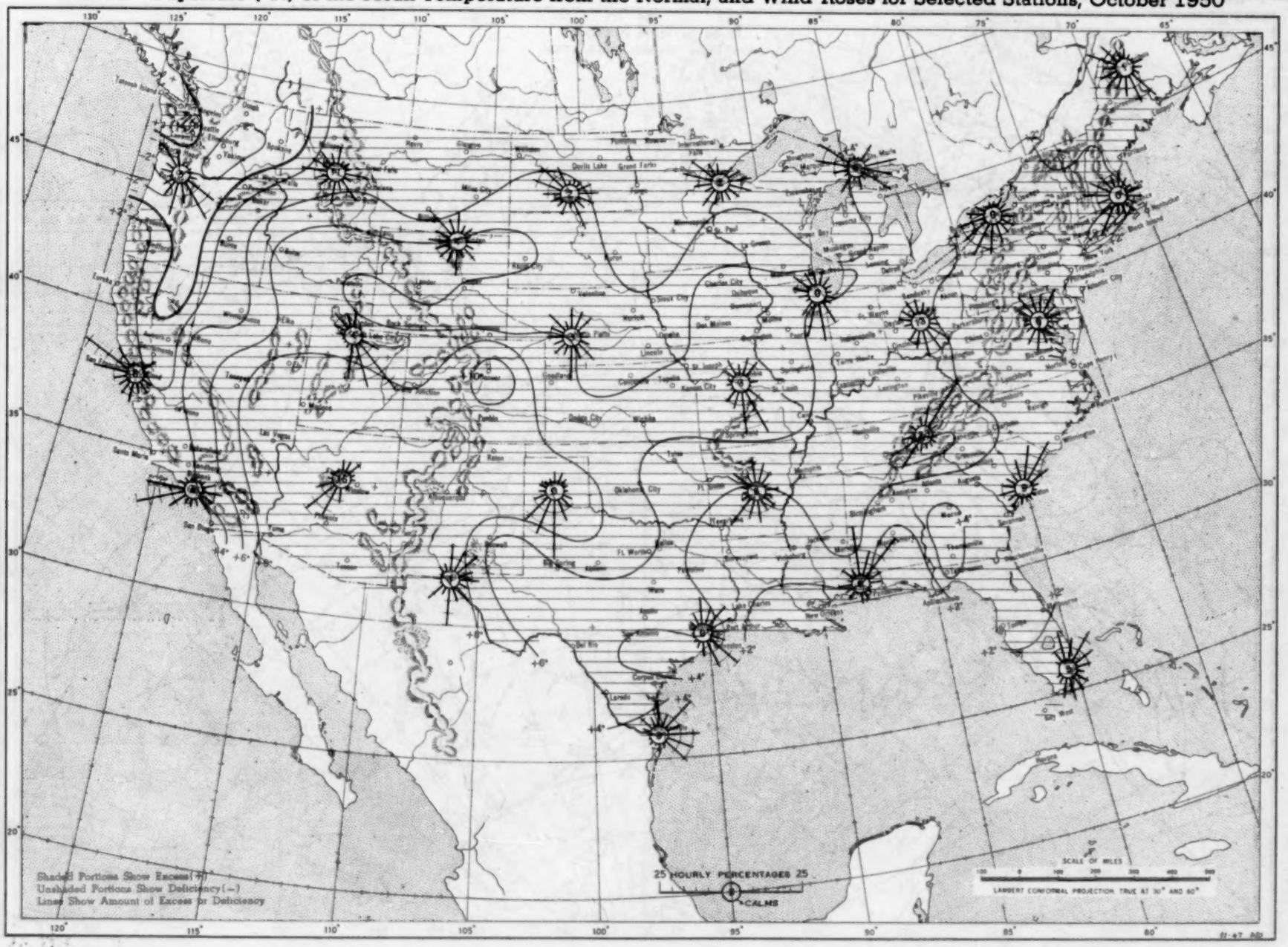
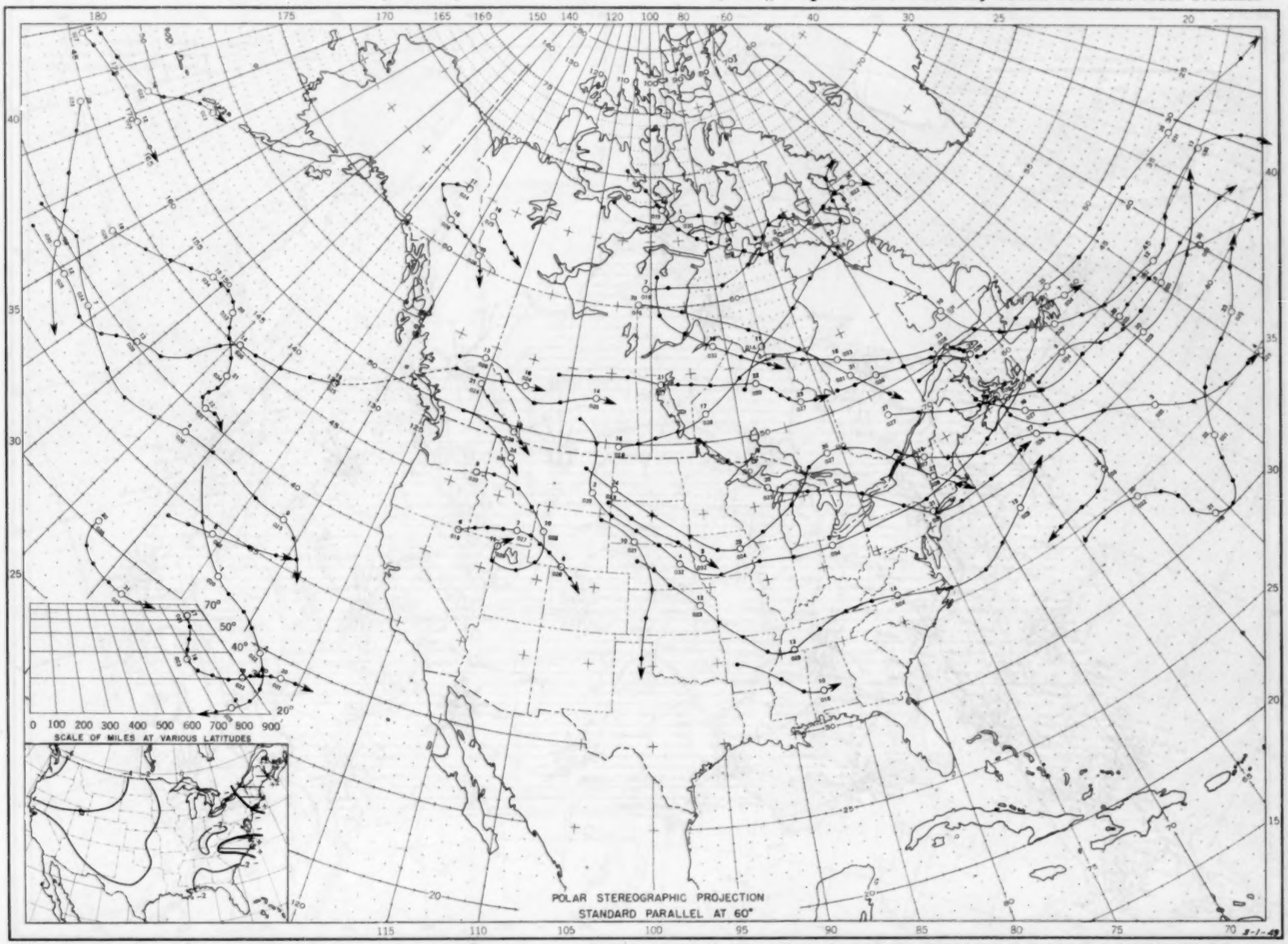
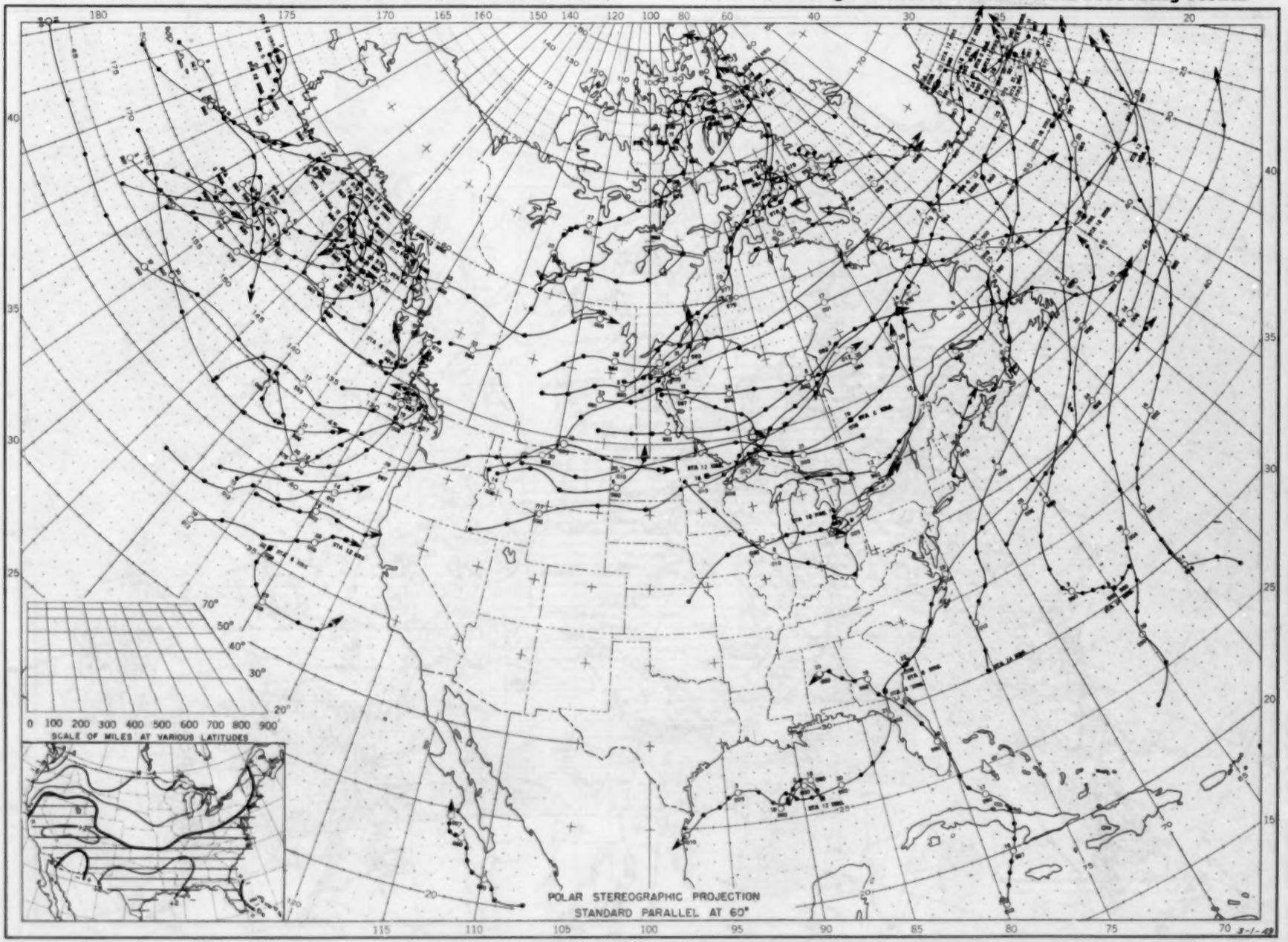

Shaded Portions Show Excess (+)
Unshaded Portions Show Deficiency (−)
Lines Show Amount of Excess or Deficiency
25 HOURLY PERCENTAGES 25
CALMS
SCALE OF MILES
LAMBERT CONFORMAL PROJECTION, TRUE AT 30° AND 60°

Chart II. Tracks of Centers of Anticyclones, October 1950. (Inset) Departure of Monthly Mean Pressure from Normal



Circle indicates position of anticyclone at 7:30 a. m. (75th meridian time). Figure above circle indicates date, and figure below, pressure to nearest millibar. Dots indicate intervening 6-hourly positions. Square indicates position of stationary center for period shown. Only those centers which could be identified for 24 hours or more are included.

Chart III. Tracks of Centers of Cyclones, October 1950. (Inset) Change in Mean Pressure from Preceding Month



Circle indicates position of cyclone at 7:30 a. m. (75th meridian time). Figure above circle indicates date, and figure below, pressure to nearest millibar. Dots indicate intervening 6-hourly positions. Square indicates position of stationary center for period shown. Only those centers which could be identified for 24 hours or more are included.

Chart IV. Percentage of Clear Sky Between Sunrise and Sunset, October 1950

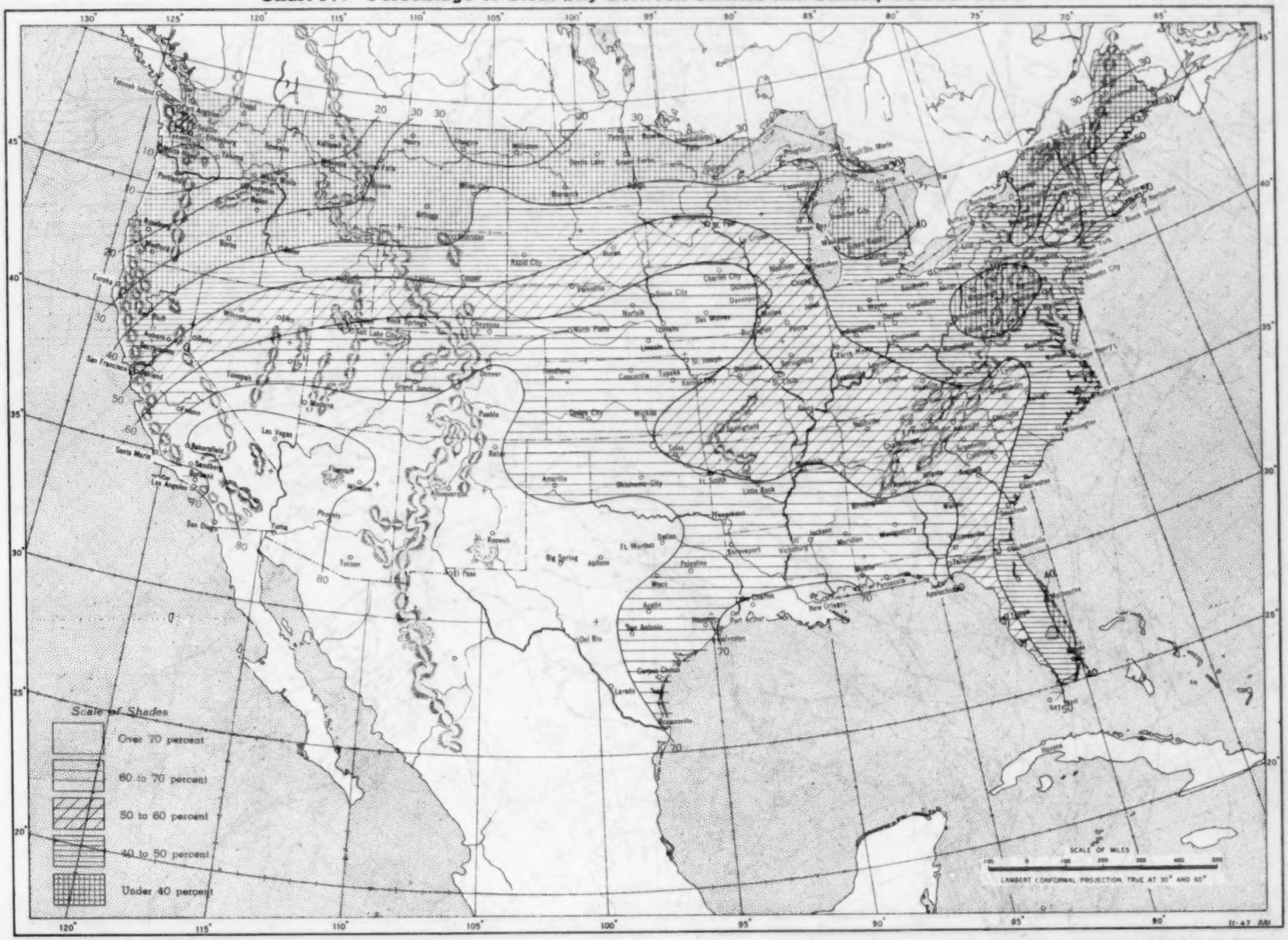

Scale of Shades
Over 70 percent
60 to 70 percent
50 to 60 percent
40 to 50 percent
Under 40 percent
SCALE OF MILES
LAMBERT CONFORMAL PROJECTION, TRUE AT 30° AND 60°

Chart V. Total Precipitation, Inches, October 1950. (Inset) Departure of Precipitation from Normal

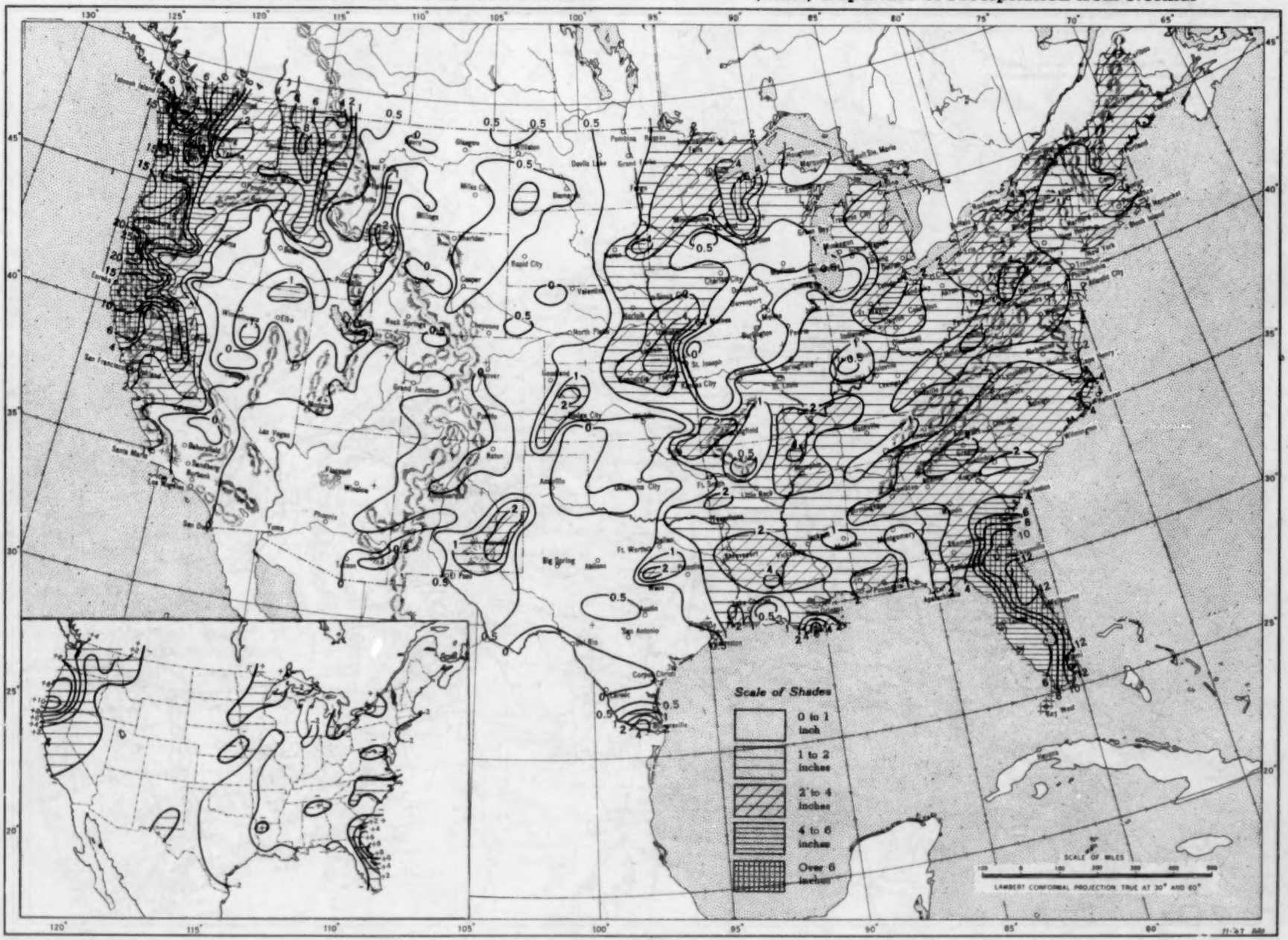

Scale of Shades
0 to 1 inch
1 to 2 inches
2 to 4 inches
4 to 6 inches
Over 6 inches
SCALE OF MILES
LAMBERT CONFORMAL PROJECTION TRUE AT 30° AND 60°

Chart VI. Mean Isobars (mb.) at Sea Level and Mean Isotherms (°F.) at Surface., October 1950

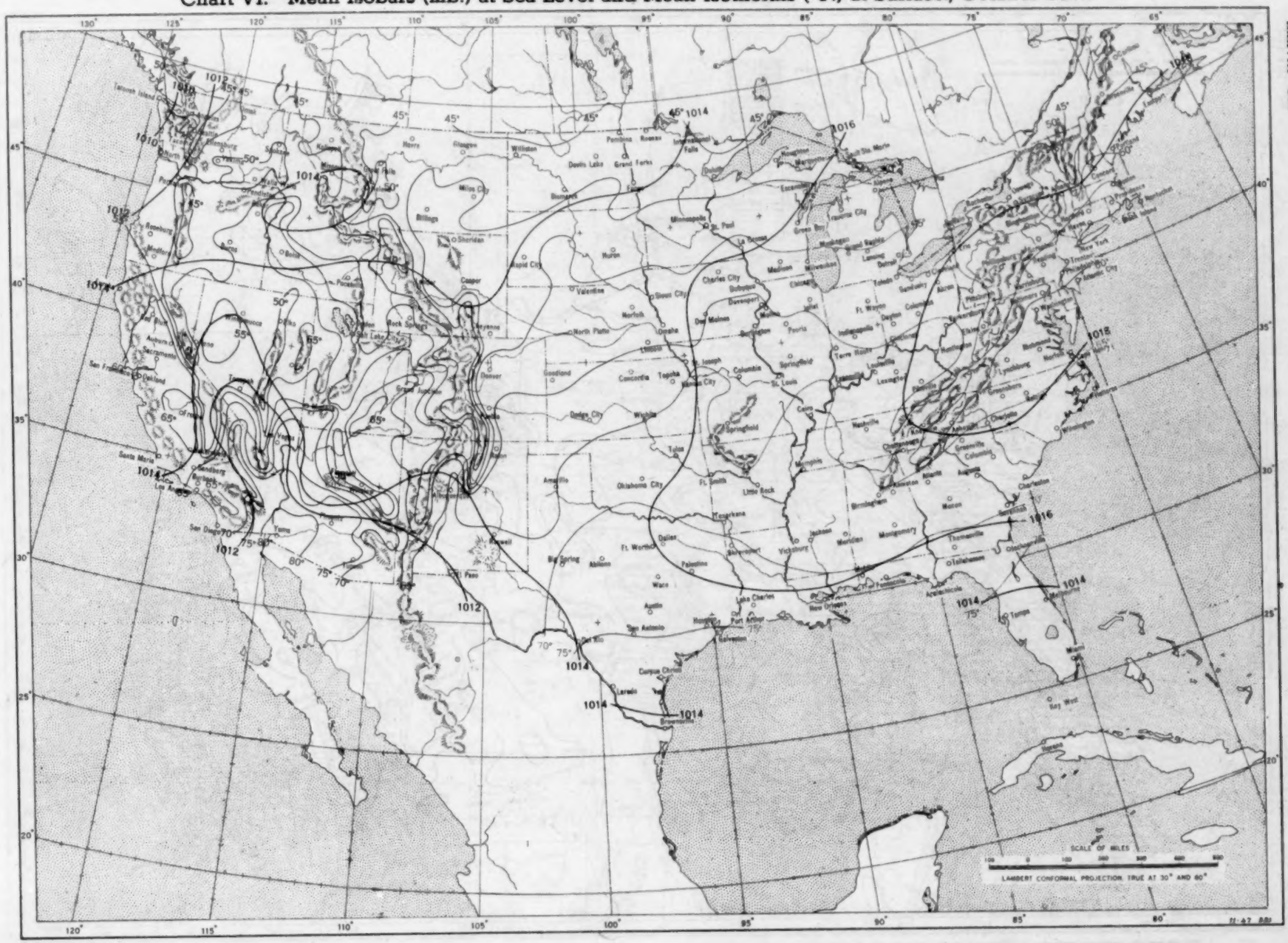
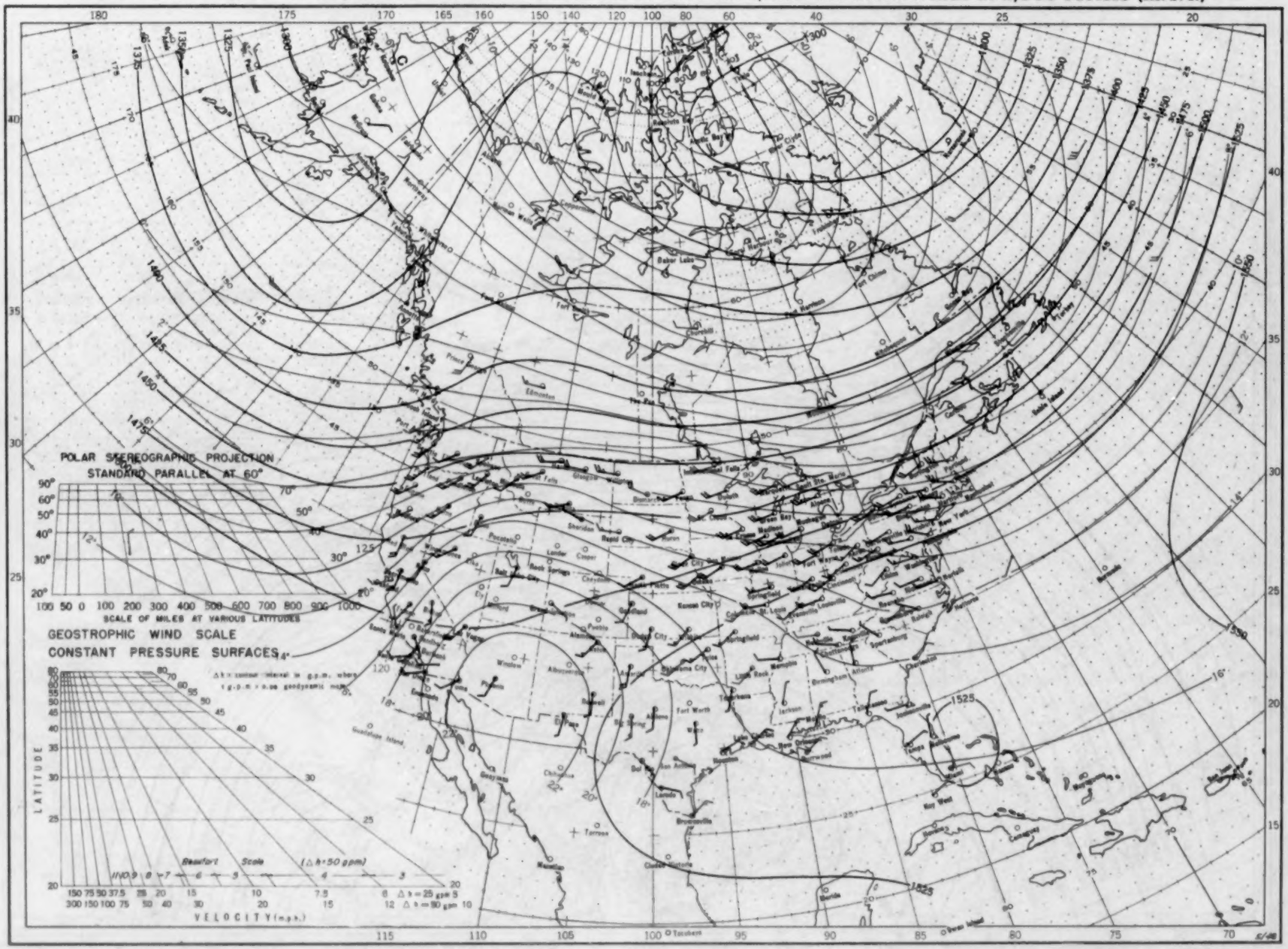
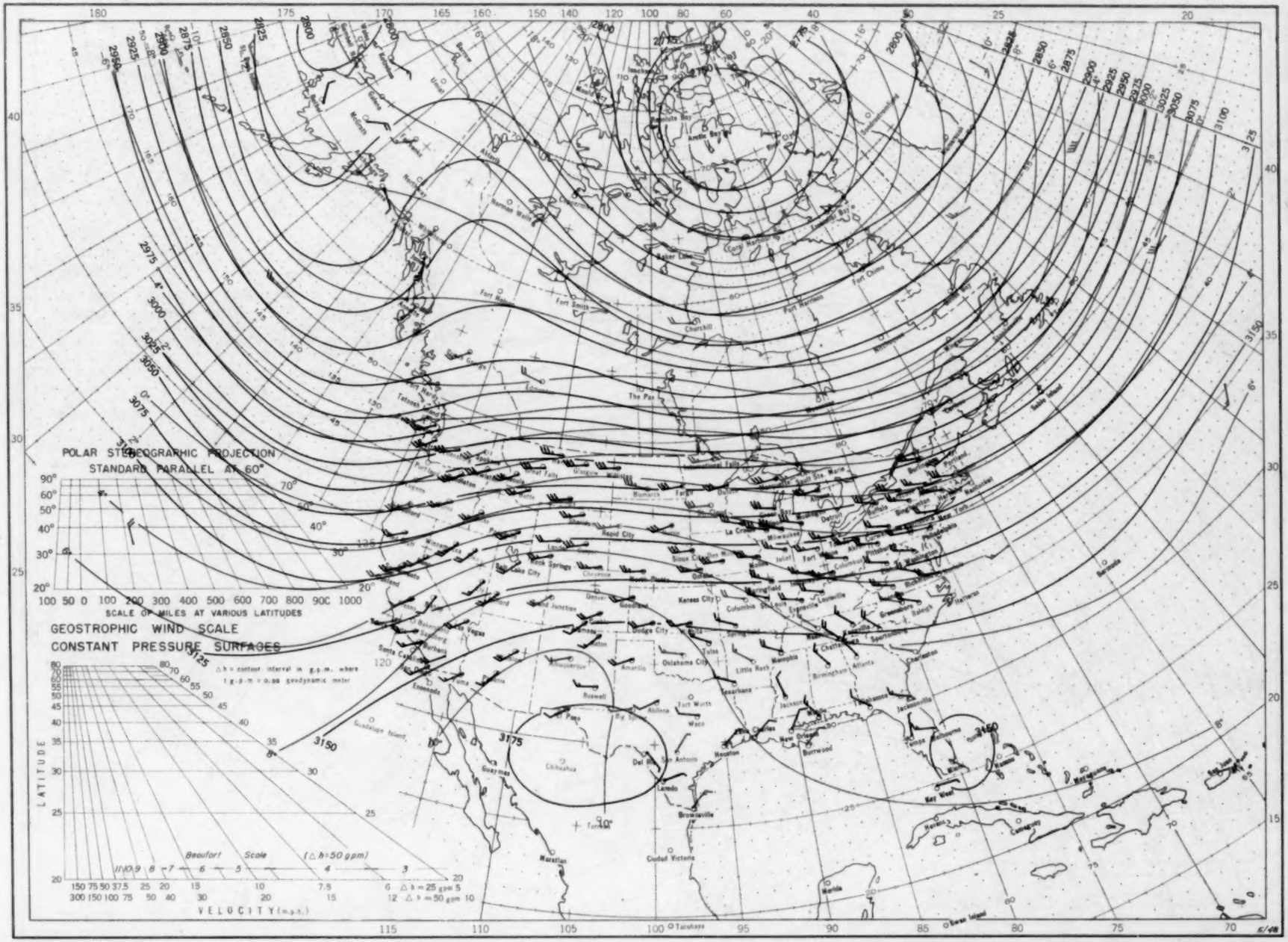


Chart VIII, October 1950. Contour Lines of Mean Dynamic Height (Geopotential) in Units of 0.98 Dynamic Meters and Mean Isotherms in Degrees Centigrade for the 850-millibar Pressure Surface, and Resultant Winds at 1,500 Meters (m. s. l.)



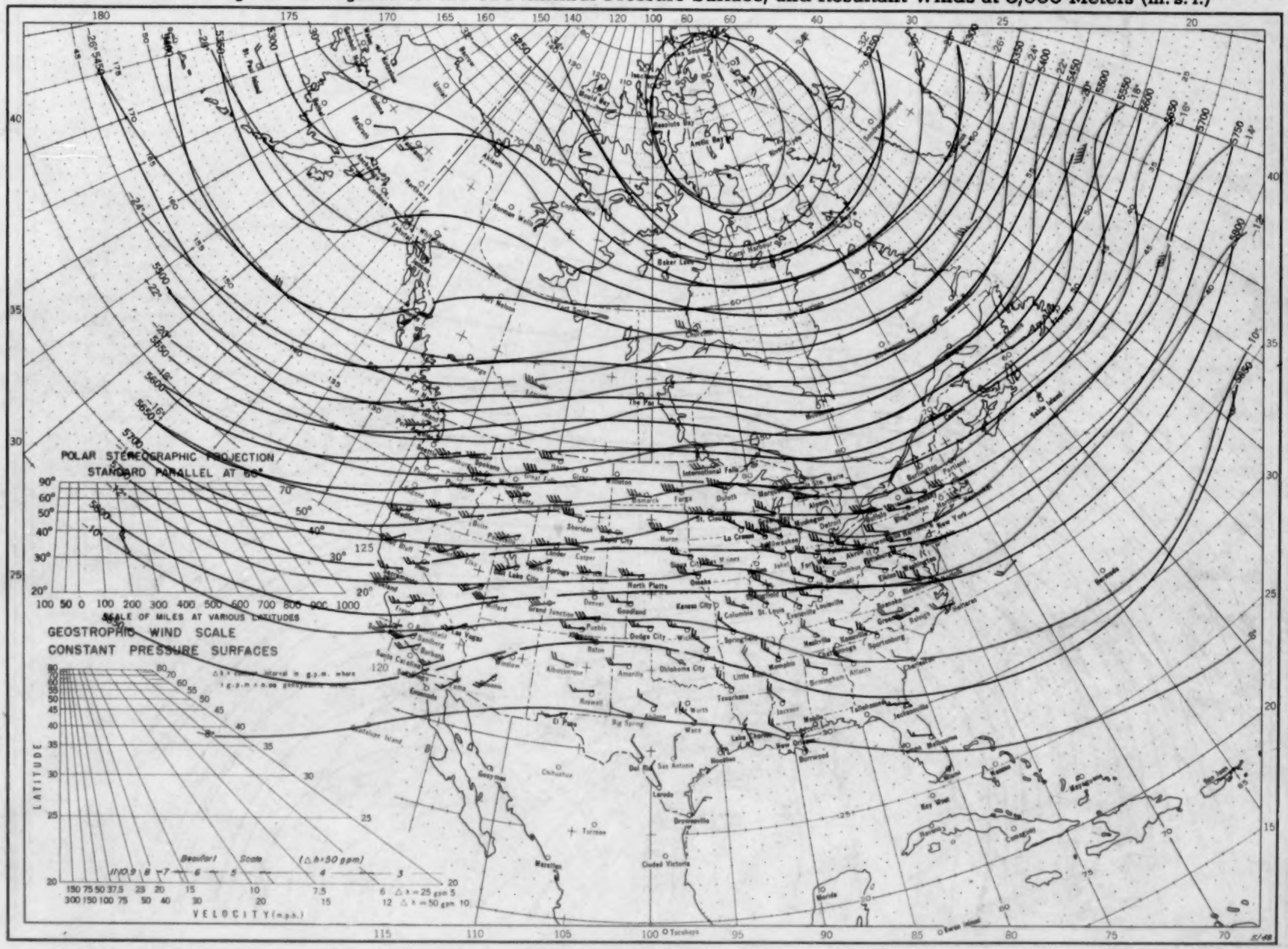
Contour lines and isotherms based on radiosonde observations at 0300 G. C. T. Winds indicated by black arrows based on pilot balloon observations at 2100 G. C. T.; those indicated by red arrows based on rawins taken at 0300 G. C. T.

Chart IX, October 1950. Contour Lines of Mean Dynamic Height (Geopotential) in Units of 0.98 Dynamic Meters and Mean Isotherms in Degrees Centigrade for the 700-millibar Pressure Surface, and Resultant Winds at 3,000 Meters (m. s. l.)



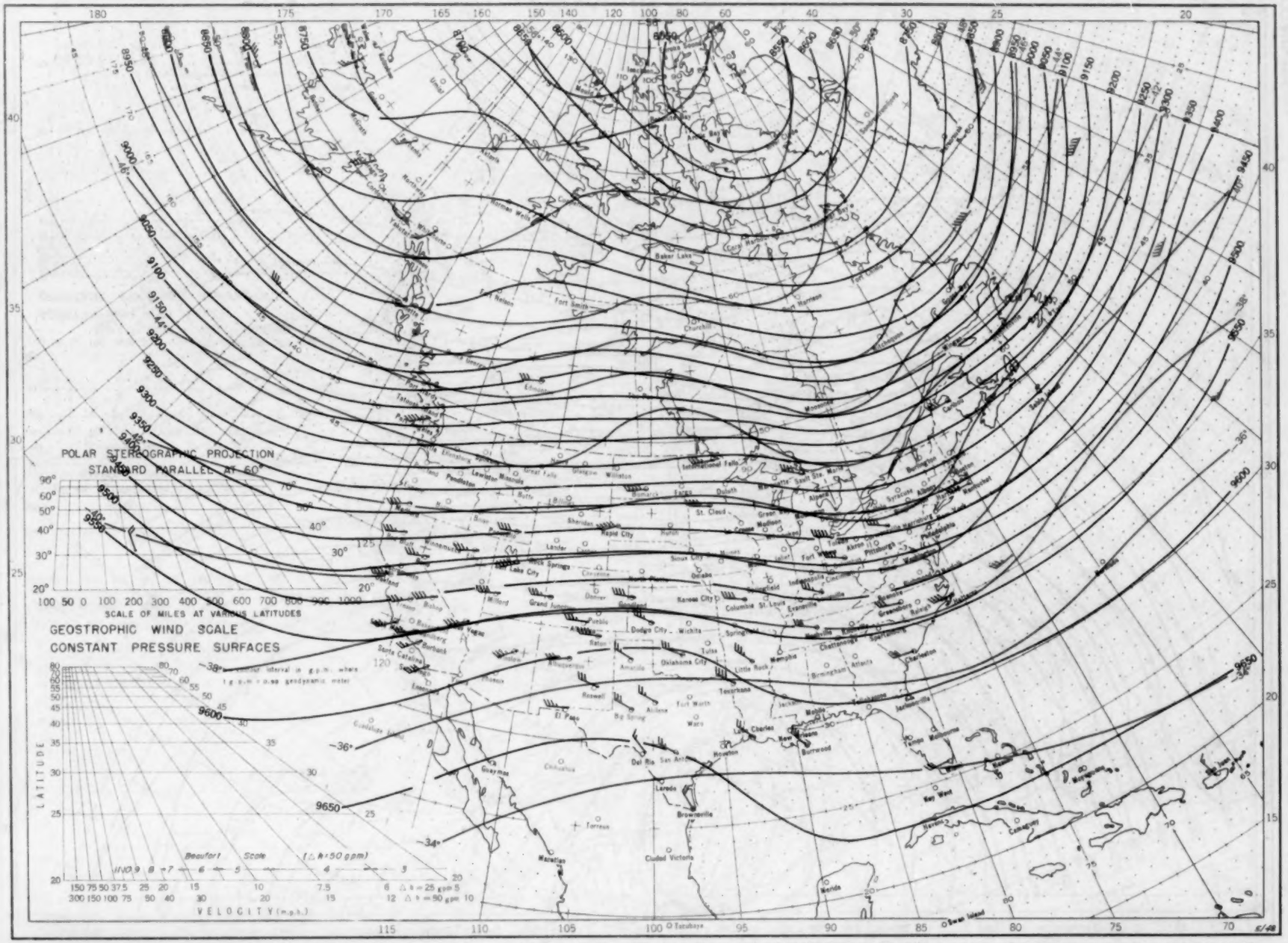
Contour lines and isotherms based on radiosonde observations at 0300 G. C. T. Winds indicated by black arrows based on pilot balloon observations at 2100 G. C. T.; those indicated by red arrows based on rawins taken at 0300 G. C. T.

Chart X, October 1950. Contour Lines of Mean Dynamic Height (Geopotential) in Units of 0.98 Dynamic Meters and Mean Isotherms in Degrees Centigrade for the 500-millibar Pressure Surface, and Resultant Winds at 5,000 Meters (m. s. l.)



Contour lines and isotherms based on radiosonde observations at 0300 G. C. T. Winds indicated by black arrows based on pilot balloon observations at 2100 G. C. T.; those indicated by red arrows based on rawins taken at 0300 G. C. T.

Chart XI, October 1950. Contour Lines of Mean Dynamic Height (Geopotential) in Units of 0.98 Dynamic Meters and Mean Isotherms in Degrees Centigrade for the 300-millibar Pressure Surface, and Resultant Winds at 10,000 Meters (m. s. l.)



Contour lines and isotherms based on radiosonde observations at 0300 G. C. T. Winds indicated by black arrows based on pilot balloon observations at 2100 G. C. T.; those indicated by red arrows based on rawins taken at 0300 G. C. T.